Epidemiology and Management of Downy Mildew of Isabgol: A Review

ABSTRACT

The downy mildew of Isabgol caused by *Peronospora plantaginis* is a major limiting factor for its production and productivity. The disease appears in severe form every year and caused extensive quantitative as well as qualitative damage to the crop and makes the cultivation of Isabgol unprofitable. It causes a variety of symptoms on leaves such as chlorotic patches accompanied by ashy-white downy growth. The variations in the incidence and severity of downy mildew depend on the environmental conditions. During favourable environmental conditions, it causes serious yield reduction. Since no resistant varieties are available against this disease; therefore, the use of chemical fungicides is the only option available to the farmers to control this disease. However, it can effectively be controlled by the use of chemicals but larger breeding programmes to evolve resistant varieties need to be initiated

Keywords: Isabgol, *Peronospora plantaginis*, symptoms, epidemiology, resistance, fungicides.

Introduction

Isabgol (*Plantago ovata* Forssk.) is the most important and commercially grown medicinal crop in India for its dietary fibre. Isabgol has great demand and is traded in major medicinal drug markets of the world. The use of *Plantago* species as sources of pharmaceutical drugs is reported by (1). The seed and husk of Isabgol are mild laxatives, emollient and demulcent. It is considered a safe laxative particularly beneficial in case of habitual constipation, chronic diarrhea, and dysentery. The seed and husk are also used to cure inflammation of the mucous membrane of gastro-intestinal and genio-urinary tracts, duodenal ulcers, gonorrhea, and piles. Isabgol mucilage has a remarkable property as a thickener and is therefore also used for making ice cream in the west. Seeds after removal of husk are by-products of the Isabgol industry and are now used as a supplement in various

diversified food products such as bread, cookies, and ice-cream stabilizer (2, 3). Seeds without husk are rich in protein and used as cattle feed as its seed oil possesses the property of reducing the cholesterol level of serum in rabbits (4).

The crop is affected by different biotic and abiotic factors, among which downy mildew caused by *Peronospora plantaginis* is a major limiting factor for its production and productivity. The disease appears in severe form every year and caused extensive quantitative as well as qualitative damage to the crop and makes the cultivation of Isabgol unprofitable (5). It causes a variety of symptoms on leaves such as chlorotic patches accompanied by ashy-white downy growth. During favourable environmental conditions, it causes serious yield reduction (6). Since no resistant varieties are available against this disease; therefore, the use of chemical fungicides is the only option available to the farmers to control this disease. Attempts have been made to develop fungicidal management practices for this disease (7,8,9,10). Fungicides such as aureofungin, dithane M-45, and ridomil MZ are effective against downy mildew. But usually, farmers are not adopting these in their spray schedule.

The wilt disease of isabgol caused by *Fusarium oxysporum* species complex is one of the economically important diseases in India. The pathogen survives in soil on plant debris and invaded crop plants at any stage - from germination to maturity - and drastically imposed the production. The disease incidence is influenced by several agronomical and environmental factors and varied from 10 to 60% prevalence. The fungal colony appeared white to purplish with cottony mycelium growth on Potato Dextrose Agar. The macro-conidia were oval to the slightly curved shape and septate in 2–4 cells with tapering pointed ends. The *F. oxysporum* species complex induced typical wilt symptoms on mature isabgol plants whereas, damping-off symptoms in the seedling stage (11).

A survey of literature on the pertinent aspects of the proposed investigation “Epidemiology and management of downy mildew of Isabgol”, reveals that not much information is available on these aspects. However, works done by earlier workers relating directly or indirectly to the different aspects of the investigation are reviewed.

Economic importance

Downy mildew caused by *Peronospora plantaginis* resulted in poor growth of plants resulting in lesser yield (7). The varying degrees of losses in seed yield and quality depending upon the disease intensity on the plant have been observed due to downy mildew of Isabgol caused by *Peronospora alta* (12). It was observed that *Pseudoperonospora plantaginis* caused a reduction in seed yield up to 28.8% in the Udaipur region (9). The reduction in Isabgol yields with an increase in the disease intensity was also noticed. The lowest seed yield (6g/plant) was observed with the highest disease intensity (61.7%). The test weight and swelling capacity of seeds were also decreased as the disease intensity increased (13).

Morphological and Symptomatological studies

The downy mildew of Isabgol (*Plantago ovata* Forssk) is a serious disease, which is prevalent wherever the crop is grown. A perusal of available literature indicates that the disease is incited by two different species, *Peronospora* and *Pseudoperonospora* species. It was reported that *P. plantaginis* Underwood develops chlorotic areas on the upper surface of leaves and ashy-white frost-like mycelium growth on the lower surface (7). Later on, infected leaves become chlorotic and brown followed by curling, crinkling, and drying ~~of~~ leaves, which results in poor growth of the plant and flowering. It was observed that *P. alta* Fukel, is the incitant of downy mildew of Isabgol. The symptoms are incited as chlorotic streaks extending along the midrib of the leaves. Profound downy growth was observed on the lower surface. Ultimately, the whole leaf turned necrotic and in severe cases, the entire plant gave a blight appearance. The abundant oospores formation caused the thickening of affected leaves. (14). Later, *P. plantaginis* was reported to be the causal agent of downy mildew of Isabgol in Southern parts of Rajasthan (15). The disease is recognized by two types of symptoms viz. systemic and localized. In systemic infection, the diseased plants initially become chlorotic white, and leaves were covered with ashy-white fungal growth on both the surfaces. In

localized infection, pale brown spots appeared on leaves which later turned around necrotic, and in severe cases, the entire plant gave a blighted appearance.

The fungus belongs to Family *Peronosporaceae* of Order *Peronosporales*, Class *Oomycetes* and Phyllum *Oomycota*. The important characteristics of the fungus are; the mycelial hyphae non-septate, intercellular, hyaline, thin-walled, bearing intercellular, branched, finger-like haustoria. The oospores are globose, smooth-walled, and yellowish-brown about 31.10 to 46.0 µm (15). The group of downy mildew fungi is an obligate parasite characterized by invasion of host tissues intercellularly and limited intrusion into the host cell by haustoria. The stomata provide a stimulus for penetration (16). According to them, stomatal penetration is fairly common in the downy mildew and the greater development of sporangiophores on the lower surface of leaves may be due to a large number of stomata in many host species. The conidia of *Peronospora plantaginis* causing disease on *Plantago complexicaulis* measured as 40-44 x 16-18 µm in size (17). The mycelium of *Peronospora alta* was observed to be as intercellularly and haustoria hyphae infrequent. It was reported that conidiophores 290-450 x 8 µm, trunk 91-268 µm, branching obscurely dichotomous 4-6 time, branch ends 8-20 x 2-3 µm, slender, tapering and curved angle usually less than a right angle, conidia 26-32 x 18-24 µm, ellipsoid, pale brown –violet (18).

The morphology of *Peronospora* and *Pseudoperonospora* (19) indicates that the main difference in these two genera is the mode of germination of asexual spores. In *Peronospora,* asexual spores germinate by germ tube which develops from any part of the conidial surface whereas, in *Pseudoperonospora,* germination of asexual spores is accomplished by the production of zoospores.

Epidemiological studies

Variations in the incidence and severity of downy mildew depend on the environmental conditions, which govern various factors like spore production, spore germination, infection, and development of the pathogen. The conidia of downy mildew require higher relative humidity for germination (20, 21, 22) and observed that 19ºC was optimum for *Peronospora arborescens* conidial germination (36.1%). It was reported that

conidia of *Peronospora trifoliorum* germinated 11.7% at 5ºC and zero per cent at 30ºC, while light did not decrease germination but inhibited germ tube growth (23). The conidia of *Peronospora plantaginis* germinated significantly more at 20ºC and least at 40ºC (24). The enhanced germination of sporangia of *Pseudoperonospora cubensis* at 15ºC compared with 30 or 35ºC (25). It was reported that a temperature range of 10-12ºC and RH more than 95% were optimum for sporangial germination of *Peronospora destructor* (21). The optimum temperature for sporangial germination of *Pseudoperonospora plantaginis* was 20ºC and, at 30ºC the germination was only 2.7% (9).

The rainfall and relative humidity have a significant effect on the degree of infection in downy mildew maize (26). Relative humidity of at least 95% was essential for sporulation of *Pseudoperonospora humuli*. The optimum temperature for sporulation was observed within the range of 16 to 20ºC, any fluctuation in temperature inhibited sporulation (27). It was also observed that sporulation in continuous light or dark was lower than that under normal photoperiod. The incidence of downy mildew of hop (*Pseudoperonospora humuli*) is based on the weather parameters viz. temperature, relative humidity, and amount of precipitation (28). The day temperature of 25 to 30ºC, night temperature of 15 to 21ºC, and relative humidity of more than 95% favored the infection of *Luffa acutangula* by *Pseudoperonospora cubensis* (29). However, the leaf wetness duration of 4-6 hrs at 20ºC and 6-8 hrs at 15ºC was necessary for significant infection of *Brassica juncea* by *Peronospora parasitica* and downy mildew development. Also, increasing the duration of leaf wetness over the range of 2-12 hrs favoured the disease (30).

It was observed that a temperature regime of 18ºC gave maximum infection frequency of *Peronospora trigonella* on fenugreek. The maximum infection (52.2%) was observed when the inoculated plants were incubated in darkness followed by 49.5% in light. Further, it was observed that maximum infection of 56.2% when inoculated leaves were kept wet for 12 h followed by 53.4 ~~%~~ and 49.1% infection after 12 and 6 h of leaf wetness. The infection and disease development increased with the age of the crop up to the flowering stage (31).

For initial development of downy mildew of Isabgol, a temperature ranged between 15 to 20ºC with high relative humidity (100% for 96h) coupled with susceptible age of the plant (70 –80 days old plant) was found essential. It was observed that the maximum disease (60.7%) occurred at 15ºC which was at par with disease intensity (60%) recorded at 20ºC. As far as relative humidity is concerned, it was observed that plants exposed to 100% relative humidity for 96 hrs expressed. The highest disease level (62%) followed by 50.9% and 50.5% at 120 and 72 hrs with 100% RH. Further, the maximum disease intensity (50.6%) and minimum incubation period (4 days) were observed when pots were covered with blue-coloured cellophane bags, and minimum disease intensity (5.3%) and the maximum incubation period (8 days) were recorded when plants were exposed to continuous darkness (32).

A continuous and significant reduction in seed yield was observed when the crop was sown on October 15 and onwards. The maximum seed yields (937 and 1114 Kg/ha) were recorded when the crop was sown on October 15 and the minimum (400 and 562 Kg/ha) when sown on December 15. It was also observed that the maximum disease intensity (45-60%) occurred when the crop was sown on normal sowing time i.e. November 15 followed by October 30 (38-48%) and October 15 (26-35%). The least disease intensity (10-15%) was recorded in December 15 sowings (10-15%) (5). An experiment was conducted at Akola where Isabgol was a newly introduced crop to find out suitable sowing time and seed rate for maximum yield. Five dates of sowing (at 10 days intervals starting from 20th October to 30th November) and three seed rates (3, 4, and 5Kg ha-1) were tried. Seed yield was significantly influenced by different sowing dates. Sowing on 20th November produced a significantly highest seed yield (3660 Kg ha-1). However, it was at par with the 10th November sowing (3450 Kg ha-1). Different seed rates did not have any significant effect on seed yield (33). Disease developed faster, when the atmospheric temperature (maximum, average 34.6±1ºC) and (minimum, average 25.0±1ºC) with relative humidity ranged above 85.5 per cent, followed by rains during the standard week of 34-36th (34). The extent of

genetic diversity in crop plants is of prime concern to plant breeders and germplasm curators (35).

The maximum disease intensity of 62.77% was observed during the second date of sowing and the least disease intensity was recorded on the third date of sowing (27.77%). The maximum average disease progression (7.50 cm) was observed on the first date of sowing and a minimum of 6.49 cm on the third date of sowing. As the disease intensity increased AUDPC values also increased and these values were almost similar for all four varieties with the date of sowing. The apparent infection rate increased to a greater extent from the first date of sowing to the second date of sowing thereafter, decreased during the third date of sowing (36).

Disease management

Chemical control of downy mildew is most practical. Several non-systemic and systemic fungicides have been tried for the control of downy mildew in various crops. However, metalaxyl, a systemic fungicide, has been reported to be widely used for seed treatment, foliar application, and soil treatment against oomycetous pathogens (37). The control of downy mildew of various crops like grapes (*Plasmopara viticola*), Squash (*Pseudoperonospora cubensis*), and tobacco (*Peronospora tabacina*) by foliar application of metalaxyl @ 125-250 g a.i./ha. Further, it was advocated that the complete control of the downy mildew disease required two to three sprays, the first spray immediately after the appearance of the disease and the second and third spray after 15 and 30 days of the first spray (38). The metalaxyl has shown the preventive and curative activity against *Plasmopara viticola* on the grapevine (39). It was reported that in a glass house, *Peronospora tabacina* on tobacco was controlled by soil and leaf treatment with ridomil @ 0.1% in the field conditions. Downy mildew of grapevine caused by *Plasmopara viticola* was controlled by ridomil @ 0.5%, ridomil plus @ 0.15%, aliette (aluminium ethylphosphite) at @ 0.1%. *Peronospora manshurica* on soyabean was controlled by seed treatment with ridomil at 100g/100Kg as well as by leaf treatments with Ridomil and Ridomil plus @ 0.2%. The primary infection of hops by *Pseudoperonospora humuli* was controlled by ridomil @ 0.8g/plant and secondary

infection by ridomil plus @ 0.2% and aliette @0.25%. It is controlled the *Pseudoperonospora humuli* on hops and *Peronospora parasitica* on cauliflower by metalaxyl (40).

The *Peronospora sparci* in boysenberry was controlled by foliar application of ridomil MZ @0.25 g a.i./litre at a weekly interval from bud burst to harvest (41). Seed treatment with apron SD-35 as a slurry at 7.5-10g/Kg and foliar application of metalaxyl at 1000 ppm (seven sprays) controlled downy mildew of opium poppy (*Peronospora arborescens*) effectively. The first spray was carried out immediately on the onset of the disease (42). Later it was found the effective control of this disease by seed treatment of Apron SD-35 @ 10g/Kg followed by three sprays of ridomil MZ at 35,55 and 75 days after sowing (43). It was reported that seed treatment with fosetyl-aluminium + mancozeb and metalaxyl + captan gave the best control of *Peronospora viciae* primary infection of the young pod crop whereas, two foliar sprays of Fosetyl-aluminium resulted in the best control of secondary infection on older plants (44). The ridomil MZ was observed as most effective in reducing downy mildew (*Peronospora destructor*) intensity on onion and increased bulb and seed yield (45). The effectiveness of ridomil-MZ in controlling the onion downy mildew was noted but repeated use of this fungicide resulted in development of resistance against the pathogen (44, 46, 47).

Metalaxyl decreased the incidence and severity of downy mildew (*Peronospora parasitica*) of rapeseed and increased yield by up to 14 per cent (48). The application of 0.5 g a.i./acre of Ridomil MZ at the planting stage reduced the occurrence of *Peronospora effusa* on spinach and at the second location, foliar application of maneb (4 lb/acre) provided the best control followed by fosetyl (2,3 and 4 lb/acre) (49). Seed treatment with apron SD-35 @ 2g a.i./Kg followed by three sprays of ridomil MZ (0.1%) at 10 days intervals beginning at the first appearance of disease controlled the Isabgol downy mildew (50).

Downy mildew (*Pseudoperonospora cubensis*) of cucumbers was effectively controlled by applying fosetyl-AI in the field and greenhouse (51). The effectiveness of chlorothalonil and fosetyl against downy mildew of melons (*Pseudoperonospora cubensis*) was reported when the sprays of the fungicides were made just at the appearance of

symptoms (52). The metalaxyl + mancozeb were most effective and reduced the downy mildew severity (*Pseudoperonospora cubensis*) (53).

The efficacy of different fungicides was tested as a seed treatment or foliar sprays against downy mildew of Isabgol caused by *Peronospora alta* and observed that foliar spray with ridomil MZ-72 was found most effective with minimum disease intensity of 23.41%, followed by indofil M-45 (34.16%), akomin-40 (46.37%), blitox 50 W (49.50%) and syllit 65 W (59.50%). In the case of seed treatment, the lowest disease intensity of 44.14% was found in case of apron SD-35, followed by ridomil MZ-72 (45.54%), foltaf SD 80 (45.72%), indofil M-45 (46.93%) and bavistin (48.43%). However, on the average, seed treatment with Apron SD-35 (5g/Kg seed) followed by three sprays of Ridomil MZ-72 (0.2%) was found to be most effective in reducing downy mildew infection and in increasing seed yield (10).

It was reported that seed treatment and three foliar sprays of the combination fungicide ridomil MZ-72 (3.73% PDI) were found to be the best treatment for suppressing downy mildew (*Peronospora plantaginis*) severity as compared to control (15.06% PDI) and increased seed yield. However, seed treatment and a single dose of the ridomil MZ-72 followed by two applications of mancozeb produced maximum net return (54). The efficacy of seven fungicides antracol (0.3%), akomin (0.3%), blitox (0.3%), dithane M-45 (0.3%), fosetyl-Al (0.25%), fytolon (0.25%) and ridomil MZ-72 (0.2%) against *Peronospora plantaginis* was tested and found that three sprays of ridomil MZ-72 were found to be most effective with the highest efficacy of disease control (78.3%) followed by fosetyl-Al (75.8%), antracol (69.5%), dithane M-45 (62.8%), akomin (56.9%), blitox (56.8%) and fytolon (54.7%). However, maximum seed yield was obtained in the case of fosetyl-Al followed by ridomil MZ-72 (55). The efficacy of six fungicides i.e, apron SD-35, ridomil MZ-72, fosetyl Al, carbendazim, mancozeb and blitox against downy mildew of Isabgol caused by *Pseudoperonospora plantaginis* was studied *in vitro* and the minimum zoosporangial germination was recorded in apron SD-35 (4.81%) followed by ridomil MZ-72 (6.20%), fosetyl Al (7.50%), mancozeb (13.97%) and blitox (17.48%). Apron SD-35, ridomil MZ-72 and fosetyl Al, effectively inhibited sporangial germination at 50ppm concentration, while mancozeb and blitox also

completely inhibited sporangial germination at 200ppm. Moreover, carbendazim could not check the growth of the pathogen. In the field trials, three seed dressers apron SD-35, mancozeb, and carbendazim at four doses (0.5, 1.0, 1.5, and 2.0%) of each were evaluated. Apron SD-35 (2.0 g per Kg seed) proved the most effective with disease intensity 48.67% in reducing infection as compared to the control (62.50%) (56)

The efficacy of eight fungicides, phytoextracts, and one bio-agent for management of downy mildew of Isabgol caused by *Peronospora plantaginis* Underwood was evaluated. The seed treatment with metalaxyl (3g/Kg seed) followed by three foliar sprays of metalaxyl MZ (0.1%) at 15 days interval initiating from the appearance of disease was the most effective treatment with the least disease intensity (10.76%) and yield increased by 26.02% over control (57). The good control of downy mildew of cucumber (*Pseudoperonospora cubensis*) was achieved by *Trichoderma harzianum* under greenhouse conditions (58).

Sources of resistance:

Use of resistant variety is considered as most economic and effective control measure for plant diseases. At present, resistant variety are not available against this disease (Kapoor and Choudhary, 1976). The reactions of varieties and crosses of Isabgol to downy mildew and have observed severity of disease almost on all varieties and crosses of Isabgol (14). The least disease on EC 124345; out of eight collections of Isabgol tested against *Peronospora plantaginis.* The 30 Isabgol genotypes were screened against *Peronospora alta* under pot conditions and found only 10 resistant genotypes (59). Likewise, thirty blond *Psyllium* germplasm collections for resistance to downy mildew under artificial inoculation conditions in the field for systemic as well as non-systemic infections were screened (60). It was found that nine entries *viz.,* DRP-46, DRP-72, FR-169, KLI-7, KLI-13, RI-13, RI-88, RI-89, and RLI-38 were found free from systemic infection and categorized immune (5). Entries *viz.,* DC-619, DRP- 56,.DRP-66, DRP-73, HI-2, HI-5, KLI-34, MSB-2, and RI-87 showed resistant and 8 entries *viz.,* DRP-74, EC-42706, FR-164, G-2-1, MSB-4, MSB- 6, MSB-8, and PG-4488 were found to be moderately resistant.

Screening of 15 Isabgol genotypes against downy mildew (*Pseudoperonospora plantaginis* and *Peronospora plantaginis*) revealed that two genotypes (PB-3-1 and Gummary) were moderately resistant, and six genotypes (MIB-123, MIB-124, AMB-2, P-6, P-80, and DM-2) were resistant against the disease at MPUAT, Udaipur (61). Screening of fifteen genotypes of Isabgol against downy mildew at MPUAT, Udaipur revealed that six genotypes (PB-6-1, PS-17, Palampur-2, P-1, HI-1, MIB-125, GI-2) were moderately susceptible, while two genotypes (PB-3-1 and Gummary) were moderately resistant (MR), and six genotypes (MIB-123, MIB-124, AMB-2, P-6, P-80, and DM-2) showed resistance against Downy mildew (62). Seventy one germplasms of Isabgol against downy mildew pathogen under artificial inoculation conditions and found 18 germplasms as resistant. RJ-130, P-80 and palanpur-2 had only traces of downy mildew (63). The disease reaction in 24 downy mildew disease free mutant lines in M, generation and found 14 lines resistant while 4 lines namely viz; L-7, L-19, L-2,L-15 were 53 having less disease infestation and having higher seed yield, swelling factors and other yield component. Therefore, these lines may be used for developing downy mildew tolerant varieties and to find out long term measure to manage the disease breeding resistant variety and identification of resistant donors is essential. (64)

Seventy-nine accessions including two local wild species (*Chenopodium album* and *C. murale*) and several cultivated quinoa lines were screened for their resistance against *Peronospora farinose,* the causal agent of downy mildew disease, and found, four as highly resistant, eleven as resistant, eight showed an intermediate reaction, eleven were sensitive and seven were found highly sensitive. Accessions M2a and S938/1 were ranked resistant as they showed the longest incubation period (7 days) and latent period (12 days) and the lowest area under the diseases progress curve (4) and M24 is the most susceptible accession as it has presented the highest area under diseases progress curve (34.5) and the shortest incubation period (1 day) and latent period (3 days) (65).

Thirty-six USDA-NPGS accessions of sweet basil (*Ocimum basilicum* L.) at cotyledon and first true leaf growth stages to identify promising downy mildew (*Peronospora belbahrii*) resistant breeding lines were evaluated and recorded thirty accessions as susceptible at both growth stages (DI = 1.0). Four accessions exhibited little or no sporulation at either growth stage (DI less than 0.06), three of which showed other symptoms including chlorosis and necrosis. One accession, PI 652053, demonstrated no signs or symptoms but differed greatly from other accessions concerning leaf morphology and habit (66).

The production of cookies enriched with Isabgol can be considered as an alternative way to include this health promoter fibre in human nutrition. Isabgol-based cookies showed gradual enhancement in dietary fibre content as the amount of husk was increased in the formulation. The resultant cookies may have the potential to manage the digestion and bowel function in human subjects (67).

Conclusion:-

Isabgol crop has acquired the place of “Dollar earner” in North Gujrat and South West Rajasthan. Downy mildew caused by *Peronospora plantaginis* Underwood is one of the economically important diseases of Isabgol. The fungus produced pale brown chlorotic spots on the leaf blade accompanied by characteristics of ash-coloured downy growth on the lower surface of these patches. As the disease progressed, leaves turned yellowish due to the loss of chlorophyll. The downy mildew incidence and variations in its severity depend on the environmental conditions. The use of resistant variety is considered the most economic and effective control measure for plant diseases. Therefore, it is concluded that Isabgol is widely grown for its economic and medicinal importance. It is infected by various diseases, among which downy mildew is the most devastating disease causing considerable yield losses. However, it can effectively be controlled by the use of chemicals but larger breeding programmes to evolve resistant varieties need to be initiated.

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